Signatures of Planets in Spatially Unresolved Disks

Amaya Moro-Martín[1], Sebastian Wolf[2], and Renu Malhotra[3]

(Email: amaya@as.arizona.edu)

[1]Steward Observatory, University of Arizona, Tucson, Arizona
[2]Max Planck Institut für Astronomie, Heidelberg, Germany
[3]Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona

In anticipation of observations of unresolved debris disks with Spitzer, we are interested in studying how the structure carved by the planets affects the shape of the disk's spectral energy distribution (SED), and consequently if the SED can be used to infer the presence of extra-solar planets. We numerically model the orbital evolution of dust originated in an outer belt of planetesimals (similar to the Solar System Kuiper Belt, 35–50 AU) in the presence of different planetary configurations: Solar System-like (i.e. with multiple giant planets); single planet systems with a planet mass of 1, 3 and 10 M_{Jup} and a semimajor axis of 1, 5, and 30 AU; and a hypothetical system with no giant planets (only dust-producing planetesimals). For each of these planetary systems we calculate the equilibrium spatial density distribution of dust. We find that the trapping of dust in gravitational resonances with the planets creates a density enhancement in a ring-like structure outside the orbit of the planet, while gravitational scattering with the planet creates a clearing of dust inside the planet's orbit. The azimuthal structure of the dust disk is not predictable in detail because it depends sensitively on the times of residence in the various resonances and these are highly variable and unpredictable (for low eccentricity planets). But even though the particle dynamics are chaotic, the equilibrium radial density distribution of dust can be accurately estimated. The radial density distributions derived from each of these planetary systems are used as input for a radiative transfer code that calculates the disk SED for a representative sample of chemical compositions (from 1 to 340 μm). The SED of a dust disk generated by an outer belt of planetesimals with inner giant planets shows a significant decrease of the near/mid-IR flux due to clearing of dust inside the planet's orbit. We found that dynamical models (as opposed to simple analytical radial profiles) are needed for the following reasons: (a) when the planet is at 1 AU, it is important to estimate the enhancement of particles near the mean motion resonances, as these particles are hot and contribute significantly to the SED; and (b) when the planet is at 5 and 30 AU, it is important to determine how many particles drift inward (i.e. the depletion factor inside the gap). Finally, based on their predicted Spitzer colors, we discuss what types of planetary systems can be distinguishable from one another.